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Determination of reference intervals and comparison of venous blood gas parameters using a standard and non-standard collection method in 51 dogs

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Summary

The aim of this study was to determine reference intervals (RI) for venous blood parameters determined with the RAPIDPoint 500 (RP500) blood gas analyzer using blood gas syringes (BGS) and to determine whether immediate analysis of venous blood collected into lithium heparin (LH) tubes can replace anaerobic blood sampling into BGS. The null hypothesis was that canine venous blood samples collected in BGS and in LH tubes are comparable. Jugular blood was collected from 51 healthy dogs into a BGS and a LH tube. The BGS was immediately analyzed followed by the LH tube. The RI were calculated from BGS results. The BGS and LH tubes results were compared using paired t-test or Wilcoxon matched-pairs signed-rank test and Bland-Altman analysis. To assess clinical relevance, the bias between BGS and LH tubes was compared with the allowable total error (TEa). Values derived from LH tubes showed no significant difference for standard bicarbonate (HCO_3std), whole blood base excess (BE B), Na, K, Cl, glucose and hemoglobin (tHb). The pH, partial pressure of carbon dioxide and oxygen, actual bicarbonate, extracellular base excess, ionized Ca, anion gap and lactate were significantly ($p < 0.05$) different from the samples collected in BGS. Lactate had a mean bias value within the recommended TEa with one sample exceeding TEa. In conclusion, HCO_3std, BE B, tHb, Na, K, Cl, Glc and Lactate can be determined within 5 minutes from blood collected in LH tubes using the RAPIDpoint500 analyzer.

Keywords: canine, acid base, ionized calcium, lactate

Bestimmung der Referenzintervalle von venösen Blutgasparametern bei 51 Hunden und Vergleich der standardisierten mit einer nicht-standardisierten Untersuchungsmethode

Ziel dieser Studie war es, Referenzintervalle (RI) für den Blutgasanalysator RAPIDPoint 500 (RP500) für venöses Blut in Blutgasspritzen (BGS) zu bestimmen, sowie festzustellen, ob eine sofortige Analyse von Blut, das in Lithiumheparin-Röhrchen (LH) gesammelt wurde, die anaerobe Blutentnahme in BGS ersetzen könnte. Die Hypothese ist, dass Blutproben in BGS und LH-Röhrchen vergleichbar sind. Von 51 gesunden Hunden wurde Jugularblut in BGS und LH entnommen, sofort auf dem RP500 analysiert und RI aus BGS Resultaten berechnet. Die BGS und LH Resultate wurden mittels gepaarten t-Test- oder Wilcoxon-Vorzeichen-Rang-Test sowie Bland-Altman-Analyse verglichen. Um die klinische Relevanz zu beurteilen, wurde der Bias zwischen BGS und LH mit dem zulässigen Gesamtfehler (TEa) verglichen. Zwischen BGS und LH ergaben sich keine signifikanten Unterschiede für Standard-Bikarbonat (HCO_3std), Vollblut-Basenüberschuss (BE B), Na, K, Cl, Glukose und Hämoglobin (tHb). Der pH, der Kohlendioxid- und Sauerstoffpartialdruck, das tatsächliche Bikarbonat, der extrazelluläre Basenüberschuss, das ionisierte Ca, die Anionenlücke und das Laktat waren signifikant ($p < 0.05$) unterschiedlich. Laktat zeigte einen mittleren Bias innerhalb der empfohlenen TEa, mit einer einzigen Messung über dem TEa. HCO_3std, BE B, tHb, Na, K, Cl, Glc und Laktat können in LH-Röhrchen innerhalb von 5 Minuten mit dem RAPIDpoint500 analysiert werden.

Schlüsselwörter: Hund, Säure-Base Haushalt, ionisiertes Kalzium, Laktat

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Introduction

Point of care (POC) blood gas and acid base analyzers are more and more common in veterinary medicine and their introduction has increased the number of arterial and venous blood gas evaluations. The RAPIDPoint 500 (RP 500, Siemens Healthcare) allows POC assessment of blood gases, acid base status, co-oxymetry, electrolytes, glucose (Glc) and lactate (Lac) within 60 seconds from a small whole blood sample.

Manufacturers of blood gas analyzers recommend using specific blood gas syringes (BGS) with an anaerobic collection technique to obtain reliable results. However, using a multi-purpose lithium heparin (LH) tube, which subsequently can be used for analysis of other blood parameters, would be easier and cheaper. A recent study in cats (Bachmann et al., 2017) and an older study looking solely at acid-base parameters in dogs (Richey el al., 2004) have identified parameters that were comparable using LH-tubes. To date, no studies have looked at the accuracy of acid-base parameters including electrolytes, Glc and Lac in dogs when analyzed in LH tubes versus BGS.

The aim of this study was to determine reference intervals for canine venous blood parameters with the RP500 blood gas analyzer using BGS and to determine whether immediate analysis of venous blood collected into LH tubes can replace anaerobic blood sampling into BGS in dogs. The null hypothesis was that canine venous blood samples collected in BGS and their corresponding venous blood samples collected in LH tubes are comparable for the evaluated parameters when analyzed within 5 minutes on the same blood gas analyzer.

Animals, Material and Methods

The study was approved by the Swiss federal ethics committee on animal research of the Canton of Zurich (#072/2011). Dogs were recruited between January and December 2013. They were considered healthy based on history, physical examination, hematology and serum biochemistry and had to be older than 1 year. Informed owner consent was obtained for all procedures.

Blood was collected from the jugular vein with dogs in a sitting position. The dogs were not sedated. After disinfection of the skin, blood was aspirated into an air-free 10 ml syringe (Omnifix, B Braun Medical AG) using a 20 G hypodermic cannula. Subsequently 1 ml blood was immediately transferred through the needle used for venipuncture into a 1 ml BGS (BD Preset 1 ml, 30 I.U. calcium balanced lithium heparin; Becton Dickinson), followed by transferring the blood without the needle into the following tubes: 1.3 ml blood into a LH tube (35 I.U. lithium heparin per ml blood; Sarstedt), 1.3 ml blood into a potassium-EDTA tube (Sarstedt) and 1 ml blood into a serum tube (Sarstedt). The potassium-EDTA tube and the serum tube were sent to the in-house laboratory for a hematology and serum biochemical profile. Air bubbles in the BGS were immediately expelled and the syringe closed with a rubber cap. The LH tube was closed with a plastic screw cap. The BGS and corresponding LH tube were then analyzed immediately with the RP500. This analyzer uses ion-selective electrodes for analysis of pH, sodium (Na), potassium (K), ionized calcium (iCa) and chloride (Cl), modified potentiometry for partial pressure of carbon dioxide (PCO_2) (Severinghaus electrode) and amperometry for partial pressure of oxygen (PO_2) (Clark electrode), Glc and Lac (enzyme electrodes). Quality control is performed three times daily using an automatic quality control cartridge. Parameters not passing the analytical performance criteria are transiently deactivated.

Following manufacturers guidelines and in order to minimize gas changes, the BGS was immediately analyzed, followed by the LH tube. The BGS was directly connected to the sample receipt of the analyzer. For the LH tubes the screw cap was opened immediately prior to analysis and 0.2 ml of blood was aspirated into an uncoated 1 ml PVC syringe (Omnifix, B Braun Medical AG) and the syringe was then connected to the analyzer. Sixteen different parameters are provided by the blood gas analyzer including pH, $PvCO_2$, PvO_2, total hemoglobin (tHb), Na, K, iCa, Cl, anion gap (AnGap), Glc and Lac (measured by the RP 500). Actual bicarbonate (HCO_3act), standard bicarbonate (HCO_3std), whole blood base excess (BE B) and extracellular base excess (BE ecf) were calculated by the RP 500.

Statistical analysis

Data was analyzed using Excel (Microsoft Corporation) and a statistical software package (GraphPad Prism 6, GraphPad Software Inc.). Shapiro-Wilk test was performed to evaluate distribution of all parameters. In-house reference intervals based on the immediately analyzed samples collected in the BGS were determined with the Reference Value Advisor add-in for Microsoft Excel (Geffré et al., 2011). In agreement with the American College of Veterinary Pathologists (ASVCP) guidelines for the determination of reference intervals in veterinary species (Friedrichs et al., 2012), a parametric method was used (recommended for sample sizes of 20–120 samples with normal distribution). For parameters not showing normal distribution, values were box-cox transformed to achieve normality. The 90% confidence intervals (CI) were calculated for upper and lower limits according to the ASVCP guidelines. Differ-

ences between results from BGS and LH tubes were analyzed using paired t-test (confirmed normality) or Wilcoxon matched-pairs signed-rank test (rejected normality). Bland and Altman analysis was used to evaluate the agreement between the two methods (Bland and Altman, 1968). To assess the clinical relevance, the mean bias was compared with the allowable total error (TEa) of the respective parameter according to the ASVCP guidelines for allowable total error (Harr et al, 2013). For parameters not defined in these guidelines, TEa values defined for human medicine were used. For parameters where TEa is expressed in percent, % bias was calculated using BGS as the gold standard (% bias = bias/mean of BGS*100). The level of significance was set at $P<0.05$.

Results

Fifty-one healthy dogs were enrolled. Age ranged between 1 and 13 years with a median of 4 years. Several breeds were included with mixed breed (11), Flat Coated Retriever (8), Labrador Retriever (6), Beagle (4), and Golden Retriever (3) being the most common. Eighteen

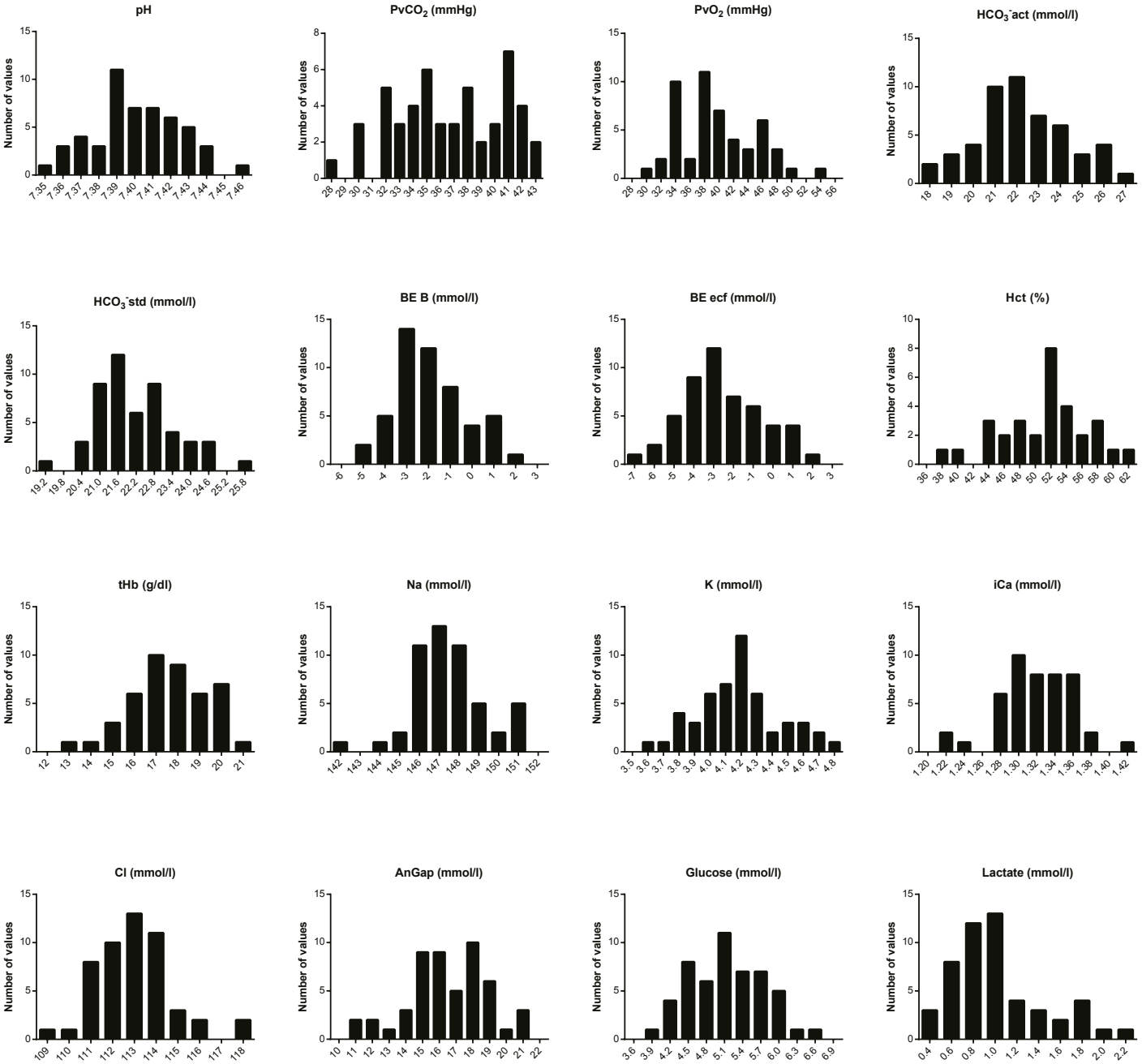

Figure 1: Histograms showing distribution of analyzed parameters in BGS for determination of reference intervals in 51 dogs.

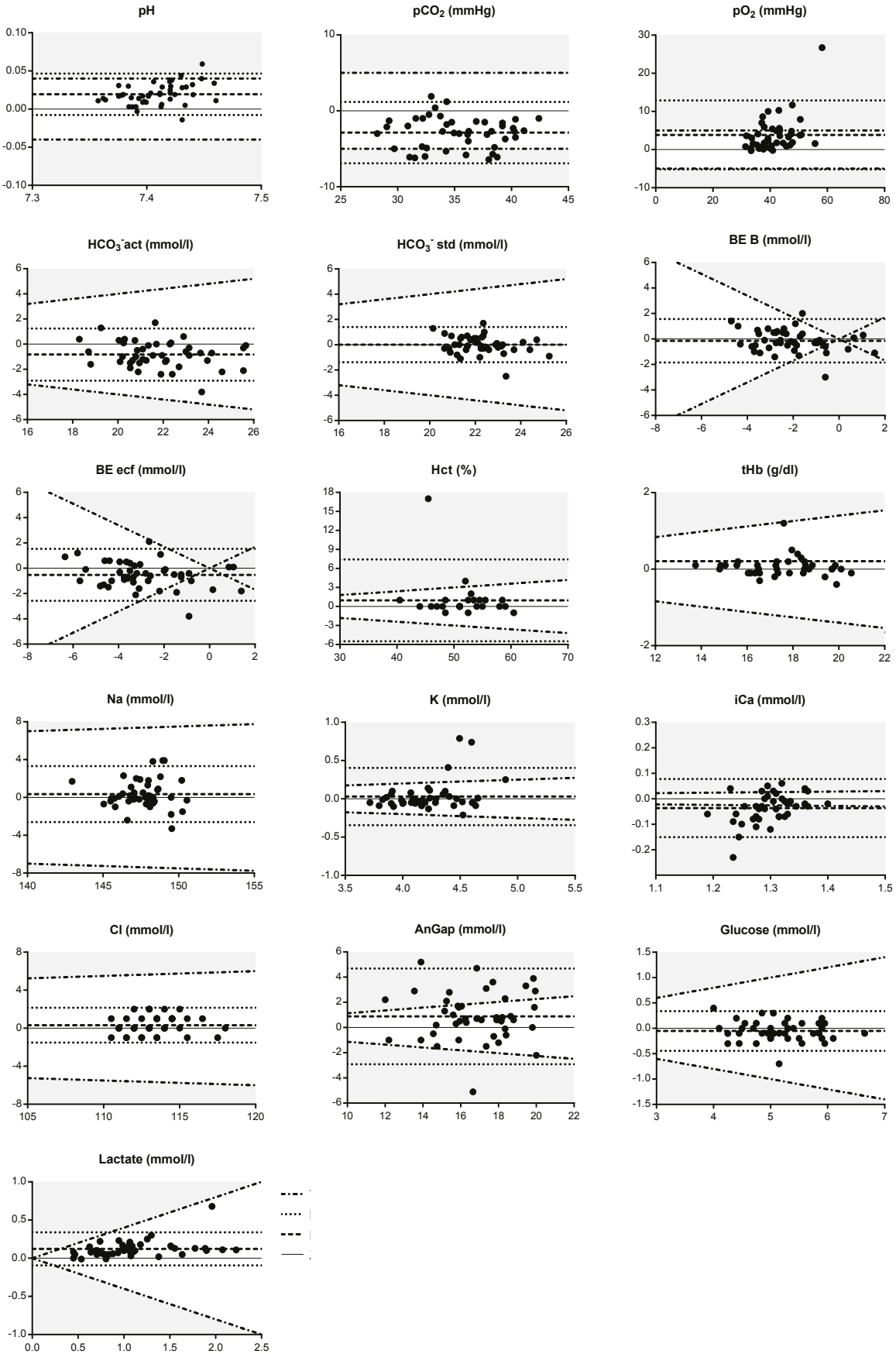

Figure 2: Bland and Altman plots comparing blood gas syringes and lithium heparin tubes. TEa: Allowable total error, LOA: limits of agreement, grey shading indicates values exceeding TEa

dogs (35%) were male (4 neutered, 14 entire) and 33 dogs (65%) female (17 spayed, 16 entire). Reference intervals were calculated from 44-51 dogs. Cl and Lac were not normally distributed while the other 14 parameters showed normal distribution. (Fig 1 and Tab 1).

Comparison of BGS and LH tubes was performed in 44 dogs. Seven dogs had to be excluded; in one dog the samples were analyzed in the wrong order and in six dogs the time between analysis of the BGS and the LH tube exceeded 5 minutes. Time between the two measurements ranged between 2 and 5 minutes with a mean of 3 minutes and a standard deviation of 1 minute.

HCO_3std, BE B, tHb, Na, K, Cl and Glc were not different between LH and BGS, while for pH, $PvCO_2$, PvO_2, HCO_3 act, BE ecf, iCa, AnGap and Lac significant differences were found (Fig 2 and Tab 2). Of the parameters with significant differences only PvO2 and iCa had a mean % bias exceeding the published TEa

Table 1: Reference intervals of canine venous blood gas parameters.

Parameter	n	Unit	Mean	Median	SD	Min	Max	Reference Interval	lower 90% CI	upper 90% CI
pH	51		7.401	7.402	0.024	7.352	7.455	7.352–7.450	7.343–7.361	7.440–4.459
$PvCO_2$	51	mmHg	36.6	36.6	4.0	28.3	42.9	28.6–44.7	27.2–30.1	43.1–46.2
PvO_2	51	mmHg	39.8	39.0	5.5	29.9	54.9	28.5–50.8	26.5–30.6	48.6–53.0
HCO_3-act	51	mmol/l	22.2	22.0	2.0	18.1	26.6	18.1–26.3	17.4–18.9	25.5–27.1
HCO_3-std	51	mmol/l	22.3	22.0	1.3	19.5	25.7	19.7–24.8	19.2–20.2	24.3–25.3
BE B	51	mmol/l	–2.0	-2.3	1.6	–5.4	2.1	–5.3 to 1.3	–5.8 to –4.6	0.7–1.9
BE ecf	51	mmol/l	–2.6	-2.9	2.0	–6.8	2.3	–6.7 to 1.5	–7.5 to –5.9	0.7–2.3
tHb	44	g/dl	17.5	17.6	1.8	12.5	20.6	13.9–21.1	13.2–14.6	20.3–21.8
Na	51	mmol/l	147.5	147.3	1.8	142.1	151.2	143.7–151.1	143.1–144.4	150.4–151.8
K	51	mmol/l	4.20	4.18	0.26	3.74	4.77	3.66–4.72	3.56–3.76	4.62–4.82
iCa	46	mmol/l	1.31	1.31	0.04	1.21	1.41	1.23–1.40	1.22–1.25	1.38–1.41
Cl*	51	mmol/l	113	113	2	110	118	109–117	109–110	116–118
AnGap	51	mmol/l	16.4	16.5	2.4	10.9	21.1	11.6–21.2	10.8–12.6	20.3–22.1
Glucose	51	mmol/l	5.1	5.1	0.6	3.8	6.7	3.9–6.4	3.7–4.1	6.2–6.7
Lactate*	51	mmol/l	1.03	0.96	0.42	0.41	2.17	0.43–2.10	0.37–0.50	1.80–2.41

n: number of samples, SD: standard deviation, Min: minimum value, Max: maximum value, CI: confidence interval.
* Parameters not showing normal distribution.

Table 2: Comparison of canine blood gas parameters determined by blood gas syringes and lithium heparin tubes.

Parameter	n	Unit	Mean BGS	Mean LH tube	Bias	95% CI	Limits of agreement		P-Value
pH*	44	–	7.399	7.418	0.019	0.015 – 0.024	–0.008	0.047	<0.0001
$PvCO_2$*	44	mmHg	36.8	33.9	–2.9	–3.5 to –2.2	–6.9	1.2	<0.0001
PvO_2*	44	mmHg	39.5	43.4	3.9	2.4–5.2	–5.2	13	<0.0001
HCO_3-act*	44	mmol/l	22.2	21.4	–0.8	–1.1 to –0.5	–2.9	1.2	<0.0001
HCO_3-std	44	mmol/l	22.2	22.2	0	–0.2 to 0.2	–1.4	1.4	0.9329
BE B	44	mmol/l	–2.0	–2.2	–0.2	–0.4 to 0.1	–1.8	1.6	0.2812
BE ecf*	44	mmol/l	–2.6	–3.1	–0.5	–0.8 to –0.2	–2.6	1.5	0.0020
tHb	38	g/l	17.4	17.6	0.2	–0.1 to 0.5	–1.7	2.1	0.1859
Na	44	mmol/l	147.5	147.8	0.3	–0.1 to 0.8	–2.6	3.3	0.1317
K	44	mmol/l	4.21	4.24	0.03	–0.03 to 0.09	–0.34	0.40	0.2999
Cl	44	mmol/l	113.1	113.5	0.4	0.0–0.6	–1.5	2.1	0.0552
iCa*	40	mmol/l	1.32	1.28	–0.04	–0.06 to –0.02	–0.15	0.08	0.0003
AnGap*	44	mmol/l	16.3	17.2	0.9	0.3–1.5	–2.9	4.7	0.0040
Glucose	44	mmol/l	5.2	5.1	–0.1	–0.1 to 0.0	–0.4	0.3	0.0892
Lactate*	44	mmol/l	1.02	1.15	0.13	0.09–0.16	–0.09	0.34	<0.0001

n: number of samples, CI: confidence interval, * Parameters showing significant (p <0.05) difference between blood gas syringes and lithium heparin tubes

(Tab 3). The other parameters showed a mean % bias within the recommended TEa, but had individual samples exceeding these limits (Tab 3).

Discussion

To the author's knowledge, this is the first study reporting canine venous blood gas RI for the RP500. Reference intervals depend on the specific method of measurement and therefore need to be determined for each analyzer. Acid-base values further vary between species (Hopper et al., 2014; Tamura et al., 2015), illustrating the importance to use species specific RIs to interpret blood gas results. Until recently, only a few studies have determined canine venous blood gas RIs and they have been established on small numbers of dogs (Ilkiw et al., 1991, Richey et al., 2004m Ha et al., 2013, Hopper et al., 2013 and 2014 and Tamura et al., 2015). A recent study determined RI for canine venous blood gas in 224 dogs using a different blood gas analyzer (Vanova-Uhrikova et al., 2017).

Our results from 51 dogs showed slightly lower $PvCO_2$ values and consequently higher pH compared with the above studies, which could be explained by the fact that in most of these studies the animals where sedated or anaesthetized during blood collection. The stress of venipuncture can lead to panting in a conscious animal and thereby lead to the observed differences. Our RI are though comparable to RI's determined in the most recent study by Vanova-Uhrikova et al., 2017 which were also performed in unsedated animals.

Comparison of blood gas syringes and lithium heparin tubes

While manufacturers recommend using specific BGS for appropriate determination of results, Richey et al (2004) investigated changes in blood gas and acid base results over time, using the same LH tubes as we did with a different analyzer. When LH tubes were kept closed until analysis, they did not find a significant change in pH, $PvCO_2$, BE and HCO_3 over 15 minutes after collection when compared to a sample that was immediately analyzed from the anaerobic BGS. Similar to this study our study also discovered that values derived from LH tubes showed no significant difference for the parameters HCO_3std, BE B, tHb, Na, K, Cl and Glc. Consequently, we conclude that abnormalities of these parameters are reliably identified with blood collected in LH tubes. In contrast to the study of Richey et al. (2004), we identified significant differences in pH, $PvCO_2$, PvO_2, HCO_3act, BE ecf, iCa, AnGap and Lac. Similar results were described in feline blood samples analyzed by the same method (Bachmann et al., 2017).

An important aspect to consider is the fact that statistical significance does not necessarily implicate clinical relevance. A difference in measured values of a certain parameter is only clinically relevant if it may lead to a different decision regarding further treatment of the patient. The threshold for relevance varies greatly between different parameters depending on how they are physiologically regulated in vivo (Farr und Freeman, 2008). Considering this, the concept of allowable total error (TEa) has been introduced in laboratory quality control. The specific TEa for a parameter of interest is derived from biological variation or a predefined clinical decision threshold and can vary between different species, analyte concentrations, type of laboratory and clinical use (Kendal et al., 2013). In veterinary medicine, the 'ASVCP TEa guidelines for biochemistry' is the only source to date and includes TEa's for Na, K, Cl, Glc, Lac and HCO_3 among other parameters (Harr et al., 2013).

Of the parameters that were significantly different between BGS and LH tubes, pH, $PvCO_2$, HCO_3 act,

Table 3: Bias or % bias compared to recommended allowable total error (TEa) of parameters that were significantly different between BGS and LH tubes when analyzed within 5 minutes.

Parameter	Bias/% bias	Range of bias	TEa	Source	Samples exceeding TEa
pH	0.019	–	0.04	CLIA	3
$PvCO_2$	–2.9 mmHg –7.9%	–6.4 to 10.1 mmHg –17.9 to 31.6%	5 mmHg or 8%	CLIA	9
PvO_2	3.9 mmHg 9.9%	–0.3 to 26.7 mmHg –0.9 to 59.6%	5 mmHg or 8%	RCPA	9
HCO_3-act	–3.6%	–14.8 to 22.6 %	20%	ASVCP	1
BE ecf	19.2%	–380.0 to 380.0%	85%	BV	6
iCa	–3.0%	–17.0 to 8.6 %	2%	BV	30
AnGap	5.5%	–26.6 to 46.0%	11.3%	BV	14
Lactate	12.7%	–1.9 to 42.0%	40%	ASVCP	1

ASVCP: American Society for Veterinary Clinical Pathology, BV: Spanish Society of Clinical Chemistry and Molecular Pathology table of Desirable Quality Specifications based on Biological Variation (Update 2004), CLIA: Clinical Laboratory Improvement Amendments Proficiency Testing Limits (1988), RCPA: Royal College of Pathologists of Australasia and the Australasian Clinical Biochemist association Quality Assurance Program, TEa: total allowable error

BE ecf, Lac and AnGap showed a % bias that was lower than the recommended TEa, suggesting that the significant difference is not clinically relevant. However, while the mean bias was below recommendations for % bias, all parameters included samples exceeding TEa, suggesting that these differences could still be clinically relevant in dogs.

Lactate measured in LH tubes was significantly higher compared to BGS. The mean difference was 0.13 mmol/L, which is below the recommended TEa, with only 1 sample exceeding the TEa. We therefore suggest that lactate can be determined from LH tubes in dogs.

The main differences between the two sample containers used in this study are the exposure to room air and the anticoagulant. Exposure to room air allows diffusion of O_2 from room air with a higher PO_2 into venous blood and of CO_2 from blood with a higher PCO_2 to room air, which will change these two parameters significantly (Biswas et al., 1982). PvO_2 and $PvCO_2$ in LH tubes and BGS were significantly different and several samples exceeded the TEa.

Our study further identified a significant increase of pH, decrease of HCO_3act and BE ecf and a higher AnGap in LH tubes. These results can all be explained by the significant decrease in $PvCO_2$ due to diffusion into room air and the subsequent increase in pH in the LH tubes. The RP500 calculates HCO_3act, BE ecf and AnGap using the measured PCO_2 and pH, while HCO_3std and BE B are not influenced by changes in $PvCO_2$ or pH.

The significant difference in iCa with a bias exceeding the TEa is most likely based on the different type of anticoagulant used. Heparin complexes calcium and thereby reduces the amount of measurable ionized calcium. Commercial BGS use dry calcium-balanced lithium heparin, which contains calcium to 'balance' the amount of iCa complexed by the heparin. Human studies support the use of calcium-balanced heparin for iCa analysis (Toffaletti et al., 1989 und 1991). A rise in pH also reduces the concentration of iCa in blood. In our study iCa decreased 0.04 mmol/l in the LH tubes. This change exceeds the effect expected by the rise in pH of 0.019 according to a human study (Wang et al., 2002) and can be attributed to the non-balanced heparin that complexed iCa partially.

Conclusion

In dogs, HCO_3std, BE B, tHb, Na, K, Cl, Glc and Lac can be determined within 5 minutes from blood collected in LH tubes using the RAPIDpoint500 analyzer. For pH, PvO_2, $PvCO_2$, AnGap and iCa the clinically relevant alterations have to be considered if analyzed in LH tubes and use of a commercial BGS is recommended.

Acknowlegement

We acknowledge Siemens Healthcare Diagnostics AG, Zurich, Switzerland for the cartridges for the blood gas analyses.

Détermination des intervalles de référence des paramètres de la gazométrie veineuse chez 51 chiens et comparaison entre les méthodes d'examen standardisées et une méthode non-standardisée

Le but de la présente étude était de déterminer l'intervalle de référence (RI) de l'analyseur de gaz du sang RAPIDPoint 500 (RP500) pour du sang veineux prélevé dans des seringues pour gaz du sang (BGS) ainsi que de voir si une analyse immédiate du sang collecté dans des tubes à l'héparine de lithium (LH) pouvait remplacer la collecte anaérobe dans des seringues BGS. L'hypothèse était que les échantillons sanguins dans les seringues BGS et dans les tubes LH sont comparables. On a prélevé du sang de la veine jugulaire sur BGS et LH chez 51 chiens en bonne santé, on l'a analysé immédiatement avec l'analyseur RP500 et on a calculé les intervalles de référence

Determinazione degli intervalli di riferimento dei parametri dell'emogasanalisi venosa in 51 cani e paragone tra un metodo di esame standardizzato e uno non standardizzato

Lo scopo di questo studio è di determinare gli intervalli di riferimento (IR) per l'emogasanalizzatore RAPID Point 500 (RP500) per i gas venosi utilizzando siringhe per gas ematico (BGS) e di accertare se un'analisi ematica immediata raccolta in tubi di litio eparina (LH) potrebbe sostituire il prelievo sanguigno anaerobio con BGS. Viene ipotetizzato che i campioni di sangue prelevati con tubi BGS e tubi LH siano paragonabili. Da 51 cani sani è stato prelevato sangue con BGS e LH dalla giugulare, quindi è stato analizzato immediatamente con il RP500 e calcolato un IR dei risultati con BGS. I risultati dei tubi BGS e LH sono stati paragonati con il t-test appaiato o con il test dei ranghi con segno

pour les résultats des prélèvements sur BGS. Les résultats des prélèvements sur BGS et sur LH ont été comparés au moyen de t-test appariés ou d'un test de Wilcoxon signé ainsi que par une analyse de Bland-Altman. Pour juger de la signification clinique, on a comparé le biais entre BGS et LH avec une erreur globale admissible (TEa). Il n'y avait pas de différence significative entre BGS et LH en ce qui concerne le bicarbonate standard, l'excès basique du sang total, le sodium, le potassium, le glucose et l'hémoglobine. Le pH, les pressions partielles de gaz carbonique et d'oxygène, le bicarbonate effectif, l'excès basique extracellulaire, le calcium ionisé, le trou anionique et le lactate étaient significativement ($p < 0.05$) différents. Le lactate présentait un biais moyen compris dans la TEa admissible avec une seule mesure dépassant le TEa. HCO3std, BE B, tHb, Na, K, Cl, glucose et lactate peuvent être analysés sur des tubes LH dans les 5 minutes avec l'analyseur RAPIDpoint500.

Wilcoxon infine con l'analisi Bland-Altman. Per valutare la rilevanza clinica, la distorsione tra tubi BGS e LH è stata comparata con l'errore totale ammissibile (TEA). Tra BGS e LH non sono state rilevate differenze significative tra bicarbonato standard, eccesso di basi nel sangue intero, Na, K, Cl, glucosio ed emoglobina. Il pH, la pressione parziale dell'anidride carbonica e dell'ossigeno, il bicarbonato standard, l'eccesso di basi extracellurari, il Ca ionizzato, l'interruzione degli anioni e il lattato erano significatamente differenti ($p < 0.05$). Il lattato ha mostrato una distorsione media tra i TEa raccomandati, con un'unica misurazione di Tea superiore. HCO3 standard, BE B, tHb, Na, K, Cl, Glc e lattato sono stati analizzati usando dei tubi LH entro 5 minuti con un RAPIDpoint500.

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